

An impacts of logging operations on understory plants for the broad-leaved/Korean pine mixed forest on Changbai Mountain, China

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Abstract: Natural regeneration of tree species is important to the sustainability of native forest ecosystems in the temperate zone of north-east China. This study compared the densities and heights of seedlings and the diversities of shrubs and herbs on three sites of logging operations: log-skidding trails (LST), logging gaps (LG) and log landing sites (LLS). Sites undisturbed by logging gaps operations were sampled as control. The species, counts and height of tree seedlings and the species, counts, height and percentage coverage of shrubs and herbs were recorded in the field. The highest density and greatest height of regeneration trees were observed at LG and LST. The effects of LST on the densities of broadleaved trees were greater than those of coniferous trees. The difference in seedling density between LLS and control was significant ($p=0.05$). There was no significant difference in average seedling height for all the tree species between the disturbed sites and control. There were more shrub and herb species at the disturbed sites than at control. The diversity of understory plants at LG was the highest among all the sites. LST and LLS were different in shrub diversity, so were LLS and control. Both LG and LLS were different from control in herb diversity. Active measures need to be taken on the operation sites to protect the coniferous trees and the diversities of understory plants for sustaining the structure and composition of the broadleaved-Korean pine mixed forest on Changbai Mountain of China. Since different operation sites have different effects on different tree species, site-dependent actions must be taken to assure the regeneration of ecologically important tree species.

Keywords: Logging; Operation sites; Disturbance; Regeneration; Diversity

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Introduction

The broadleaved/Korean pine mixed forest is one of major forest types northeast China. Contiguous stands of the mixed forest are found on Changbai Mountain, lying along the border of China and North Korea. During the past four decades, tremendous amount of timbers has been harvested from the mixed forest. The sustainability of the mixed forest is important for assuring economic incomes of the local communities, biodiversity conservation in the forested landscapes, and preventing the erosion of water and soil from some major river systems. The success of its sustainability depends on the forest management, such as timber harvesting with different cutting methods and the cutting intensity. Many important studies have been carried out on the effects of timber harvesting on stand structure and composition, and understory vegetation. For example, Dong (2001 a&b) demonstrated that timber harvesting had little effects on the growth of height for Larch forests. Qiu *et al.* (1997) argued that the damage of the standing trees depends on the sizes of timbers harvested and cutting intensity. Luo *et al.* (1997) suggested that both selective and clear cutting enhanced the total plant diversity for the broadleaved/Korean pine mixed forest on Changbai

Mountain. Uttera *et al.* (2000) examined the differences of the structure for primary and managed forests in East Kalimantan, Indonesia. Most of the past studies mainly concentrated on the changes in stand structure and composition after cutting.

Timber harvesting is an integrated process, which takes place at a series of operation sites. Although the general effects of cutting on forest stands were studied, the regeneration of trees and the diversities of understory vegetation at specific operation sites were not well documented (Fredericksen *et al.* 2000; Lugo *et al.* 2000; Dykstra *et al.* 2000; Oliverica *et al.* 2000). Up to date, no report has been found on the differences in the regeneration of trees and the diversities of understory vegetation among operation sites in the temperate region of China. The aim of this study is to reveal the regeneration of trees and the diversities of understory vegetation at several operation sites within the broadleaved/Korean pine mixed forest on Changbai Mountain. The conclusion of this study may provide scientific evidences for rapid rehabilitation of operation sites and sustainable management of the mixed forest ecosystem.

Site description and method

The study area is located in Hongshi Forest Farm of Baihe Forestry Bureau in Jilin Province. (127°9′–128°55′E, 41°31′–42°28′N). Annual mean temperature is 2.2°C and annual precipitation is 700 mm. The top five dominant tree species are *Pinus koraiensis*, *Tilia amurensis*, *Quercus mongolica*, *Fraxinus mondschurica*, and *Acer mono*.

The forest stands studied were harvested with the selective cutting method in 1999 with an area of 450 hm², of which 10 hm² was used as the study area. Five operation blocks

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(sub-compartments) with similar topographic conditions were selected within the study area. The processes or types of logging operations were grouped into four operation types: logging gaps where logging occurred, log-skidding trails for moving logs out of logging gaps, log-landing sites for piling logs waiting before being transported out of the forest, and undisturbed sites (control) where no operations occurred. These forest stands were investigated in the summer of 2004.

Plots of log-skidding trails were located at least 50 m away from the edge of log-landing sites. The nearest four logging gaps on the both sides of log-skidding trails were measured. Plots of logging gaps were located approximately 50 m between each other using triangulation. A control was located at least 50 m away from any disturbed site.

Multiple plots of 10 m×10 m in size were randomly set up within each block. Totally 23 plots were measured. Each plot was further divided into subplots of 5 m×5 m in size, where tree seedlings and shrubs were recorded. At each subplot, four mini plots of 1 m×1 m in size were set at the four corners of the subplot. The mini plots were used to record herbs. All the trees below 2.5 m in height were considered seedlings in this study. Species, number and height for seedlings, shrubs and herbs were separately recorded and coverage of shrubs and herbs were also recorded.

Field data were summarized for each plot. The one-way analysis of variance (ANOVA) was used to test the differences between seedling densities and heights by using SPASS 11.0. The Shannon-Wiener Diversity Index (H'), Pielou Evenness Index (E) and Community Dominance Index (D) were calculated for shrubs and herbs layer with the following formulas (Huang Jianhui *et al.* 1997)

$$H' = - \sum_{i=1}^s (P_i) (\ln P_i) \quad (1)$$

$$E = \frac{H'}{\ln s} \quad (2)$$

$$D = \sum_{i=1}^s P_i^2 \quad (3)$$

where, H' is Shannon-Wiener diversity index, P_i is the relative importance values, and s is the number of species in the community.

The relative importance values (IV) was calculated with the following formula:

$$IV = (RH + RC + RF) / 3 \quad (4)$$

where, RH is relative height, RC is relative coverage, and RF is relative frequency.

Results

Trees seedlings observed consisted of 30 species in the study area. Six tree species from the broadleaved/Korea pine mixed forest were used to evaluate tree regenerations at the three operation sites (Table 1). The six tree species were selected because each of them represented an indicator tree species in canopy or sub-canopy layers of the broadleaved/Korea pine mixed forest on

Changbai Mountain (Wang *et al.* 1980). Seedlings at logging gaps had the highest density among the four sites. Both Log-skidding trails and control were dominated by *Pinus koraiensis* and *Abies nephrolepis*, and logging gaps were dominated by broadleaved tree species. Statistically, *Pinus koraiensis* seedlings in log-landing sites were significantly less than that in control or logging gaps ($p=0.05$); logging gaps and control had not significantly different in the density of *Abies nephrolepis* seedlings ($p=0.05$); Log-skidding trails and control had significant difference in seedling density for three broadleaved tree species. The seedling density of each tree species at certain sites was much lower than that at others: Lower seedling density was found for *Pinus koraiensis* at logging gaps, *Fraxinus monshurica* and *Carpinus cordata* at undisturbed sites, *Acer mono* at logging gaps and log landing sites, *Acer ukurunduense* at log landing sites, and *Abies nephrolepis* at logging gaps and log landing sites (Table 1).

Table 1. Seedling densities (stems · m⁻²) of selected six tree species at four operation sites in the broadleaved/Korean pine mixed forest on Changbai Mountain^a

Species	Log-skid ding trails	Logging gaps	Log-land ing sites	Control
<i>Pinus koraiensis</i>	0.16 ab	0.04 c	0.08 bc	0.25 a
<i>Fraxinus monshurica</i>	0.12 b	0.35 ab	0.28 ab	0.05 a
<i>Acer mono</i>	0.28 a	0.25 a	0.15 a	0.20 b
<i>Acer ukurunduense</i>	0.60 a	0.89 a	0.16 a	0.27 a
<i>Carpinus cordata</i>	0.30 a	0.44 ab	0.31 ab	0.26 b
<i>Abies nephrolepis</i>	0.48 ab	0.20 b	0.18 b	0.55 ac
All species	0.25 ab	0.36 ab	0.27 a	0.26 b

Note: ^aMeans with the same letter within rows are not significantly different at $p=0.05$

The heights of seedlings were relatively close at control but were different among the six tree species at each disturbed site: the tallest and shortest species were *Acer mono* and *Carpinus cordata* at log-skidding trails; *Acer ukurunduense* and *Pinus koraiensis*/*Abies nephrolepis* at logging gaps and log landing sites. *Abies nephrolepis* seedlings are the highest at control (Fig. 1). Different tree species had different growth rates in height at different sites. *Acer mono* and *Pinus koraiensis* grew faster at log-skidding trails; *Fraxinus monshurica* grew faster at log landing sites; *Acer ukurunduense* grew faster at logging gaps and log landing sites; *Carpinus cordata* grew faster at logging gaps; *Abies nephrolepis* grew faster at control ($p=0.05$). Three of the 4 broadleaved tree species (except for *Acer mono*) grew better in height at logging gaps and log landing sites than at log-skidding trails and control. On the contrary, the two coniferous tree species grew fast at log-skidding trails and control than at logging gaps and log landing sites (Fig. 1).

Totally 26 shrub species were observed at all the sites. They all appeared at log landing sites. Twenty shrub species were found at logging gaps, 18 at log-skidding trails, and 17 at control (Table 2.). The diversity index (H') is the highest in logging gaps. The diversity index are significantly different between log landing sites and control ($p=0.05$). Pielou evenness index (E) of shrubs at log-skidding trails or log landing sites is significantly different from that at control. Community dominance index (D) of shrubs is the highest at log landing sites and it is different from that at control ($p=0.05$). It shows that some shrub species are dominant at log landing sites.

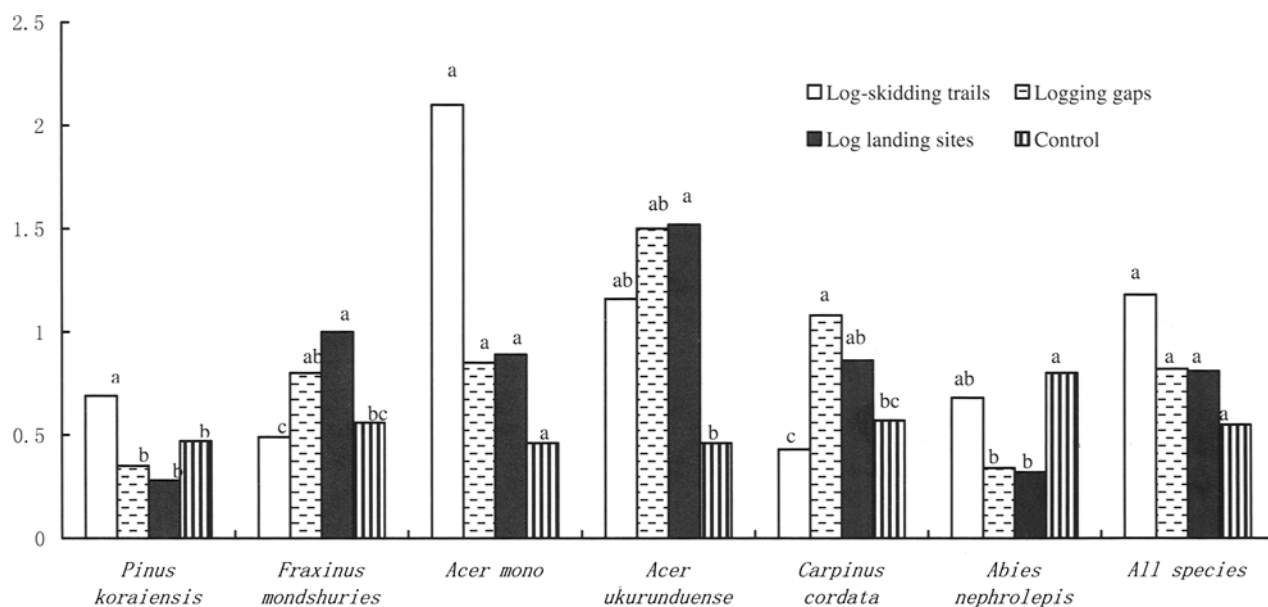


Fig. 1 Seedling height (m) of selected six tree species at operation sites in the broadleaved/Korean pine mixed forest on Changbai Mountain.

Table 2. A summary of diversity index values for the top ten frequently observed shrub species at the four operation sites.

Species	Diversity index values			
	Log-skidding trails	Logging gaps	Log-landing sites	Control
<i>Lonicera ruprechtiana</i>	66	100	42	61
<i>Acanthopanax senticosus</i>	100	50	—	56
<i>Deutzia amurensis</i>	83	76	42	56
<i>Euonymus alatus</i>	58	—	25	56
<i>Philadelphus schrenkii</i>	83	100	75	44
<i>Evonymus pauciflorus</i>	50	83	—	39
<i>Viburnum sargentii</i>	—	50	16	39
<i>Corylus mandshurica</i>	66	—	—	28
<i>Syringa amurensis</i>	58	66	—	28
<i>Actinidia arguta</i>	—	66	25	28
<i>Sorbaria sorbifolia</i>	66	50	83	—
<i>Ribes mandshuricum</i>	92	—	58	—
<i>Evonymus macropterus</i>	—	50	—	—
<i>Actinidia polygama</i>	—	—	33	—
<i>Spiraea salicifolia</i>	—	—	25	—
The number of total species	18	20	26	17
H'	2.80a	2.94ab	2.54b	2.70a
E	0.92a	0.97ab	0.90a	0.90b
D	0.05ab	0.03ab	0.09a	0.06b

Note: "—" means the species was not included in the top ten frequencies in the microsite type; ^a Means with the same letter within rows are not significantly different at $p=0.05$.

When the top ten herb species observed at control are used as a reference, about 70% of species appears on three disturbed sites (Table 3). The diversity index (H') of herbs has the highest value and the dominance index (D) is the lowest value at logging gaps. It shows that the herb species is even and there is few dominant herb species at logging gaps. The diversity index is significantly different not only between logging gaps and control but also between log landing sites and control ($p=0.05$). The difference in Pielou evenness index (E) occurred between control and log-skidding trails/log landing sites; the difference in com-

munity dominance index (D) occurred between control and log landing sites.

Table 3. A summary of diversity index values for the top ten frequently observed herb species at the four operation sites

Species	Diversity index values			
	Log-skidding trails	Logging gaps	Log-landing sites	Control
<i>Oxalis acetosella</i>	41	67	67	92
<i>Meehanian urticifolia</i>	—	100	92	83
<i>Carex callitrichos</i>	25	100	67	58
<i>Maianthemum dilatatum</i>	16	—	33	50
<i>Aegopodium alpestre</i>	41	33	—	42
<i>Brachybotrys paridiformis</i>	50	67	33	42
<i>Osmorhiza aristata</i>	—	—	—	33
<i>Osmorhiza aristata</i>	—	33	—	33
<i>Diarrhina mandshurica</i>	41	—	58	33
<i>Cardamine leucantha</i>	16	50	42	33
<i>Geum aleppicum</i>	50	—	—	—
<i>Equisetum sylvaticum</i>	50	—	67	—
<i>Osmorhiza aristata</i>	16	67	—	—
<i>Carex remotiuscula</i>	—	50	—	—
<i>Saussurea manshurica</i>	—	50	—	—
<i>Dryopteris crassirhizoma</i>	—	—	50	—
<i>Athyrium multidentatum</i>	—	—	33	—
The number of total species	42	38	41	33
H'	3.23 a	3.36 b	3.16 b	3.08 a
E	0.86 a	0.92 ab	0.88 a	0.85 b
D	0.06 ab	0.04 ab	0.07 a	0.07 b

Note: "—" means the species was not among top ten more frequently observed species at the specific site; ^a Means with the same letter within rows were not significantly different at $p=0.05$.

Discussion and conclusions

The natural regeneration of tree species was affected by logging operations. All the broadleaved tree species experienced faster growth in height at logging gaps. *Pinus koraiensis* and *Abies nephrolepis* had lower densities of seedling as well as

slower growth rates in height at logging gaps and log landing sites. Logging gaps and the log landing sites were larger in area than natural tree-fall gaps and thus provided higher light availability (Johns *et al.*, 1996). Such openings seemed unfavorable for *Pinus koraiensis* and *Abies nephrolepis* as their seedling growth requires some shading. Frederickson T. S. and Pariona W. (2002) reported that seedling density tended to be greater in scarified area than unscarified areas despite a near doubling of soil compaction in scarified areas. In this study, seedling densities of the broadleaved tree species were higher on log-skidding trails than those on control. It had a significant difference between log-skidding trails and control but their heights had not significantly difference. It can be concluded that the log-skidding promotes seed germinations but do not promote seedling growth of broadleaved tree species. The logging gaps promote seedling growth for most of tree species.

Buckley, D. S. *et al.* (2003) evaluated the impacts of haul roads and skid trails on the understory vegetation in a managed forest in upper Michigan, USA. They found understory plant richness was significantly greater in disturbed forest than undisturbed forest. But the differences in richness between trails and undisturbed forest were not statistically significant. Our results suggested that there were more shrub and herb species at disturbed sites than at undisturbed sites. The difference in shrub and herb

diversities between log-skidding trails and control were not significant, which supported the results of Buckley, D. S. *et al.* (2003). However, the difference in shrub diversity between log landing sites and control was significant ($p=0.05$). The herb diversity at logging gaps or log landing sites was significantly different from that at control. The results showed that the effect of different operation sites on the diversities of shrub and herb was different in terms of the combinations of canopy opening and understory vegetation/soil disturbance. But the overall effects of light and soil conditions altered by logging operations was generally positive for increasing the richness of shrub and herb because the more plant species was observed at disturbed sites than at control.

As far as the coniferous trees were concerned, the operation sites have negative effects on their seedling densities and growth (Table 4). Therefore, to sustain the primary forest structure and composition, active measures for the protection of coniferous seedlings must be taken on the operation sites. For example, the size of canopy opening needs to be reduced at all the operation sites and it is necessary to planting coniferous trees at the operation sites following harvest. To assure successful regeneration of dominant tree species, shrub and herb layers need to be periodically cut.

Table 4. A summary of logging operation effects on understory plants.

Item		Log-skidding trails	Logging gaps	Log-landing sites
Seedling density	Broadleaved tree species	+	+	+/-
	Coniferous tree species	-	-	-
Seedling growth	Broadleaved tree species	+	+/-	+
	Coniferous tree species	-	-	+/-
Relative sensitivity of shrubs		**	*	***
Relative sensitivity of herbs		*	***	**

Note: + means positive, - mean negative, *means sensitivity level.

The complicated effects can be explained better with micro-climates if they are monitored at different sites. Additional field observations are important. For example, (1) how does the light change in different operation sites and how does it affect the regeneration and diversity? (2) What are the roles of understory species in the managed forest ecosystems?

Logging operations are inevitable for managed forest stands. Studies about understory plant growth at operation sites can help provide scientific evidence for the forest ecosystem management. Additional studies about the effects of the size and place of operation sites on forest stands are encouraged.

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